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This thesis outlines the use of the Training-Modeling Integration process for development of training information. High resolution simulations portray weapon system operations in sufficient detail for the training developer to use the simulation to formulate task information and training insights. Training developers have relied heavily on observable information for developing training. Throught the use of the TM-I process, training developers can now use high resolution simulations to observe system employment and operation. Straightforward data analysis techniques are used to analyze simulation derived data files. The unique nature of this methodology is embodied in the synthesis of training development needs, analytical techniques and high resolution simulation data.

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Use of High Resolution Simulations for Training Development

by

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requirements for the degree of

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ABSTRACT

This thesis outlines the use of the Training-Modeling Integration TM-I process for development of training information. High resolution simulations portray weapon system operations in sufficient detail for the training developer to use the simulation to formulate task information and training insights. Training developers have relied heavily on observable information for developing training. Throught the use of the TM-I process, training developers can now use high resolution simulations to observe system employment and operation. Straightforward data analysis techniques are used to analyze simulation derived data files. The unique nature of this methodology is embodied in the synthesis of training development needs, analytical techniques and high resolution simulation data.

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I. INTRODUCTION

High resolution combat simulations have been used extensively in the military for over 20 years. Their primary use has been to gain insight into the character and nature of the major elements in a battle. The use of high resolution models have been confined almost exclusively to hardware evaluation and force structure analyses. Through the use of these simulations the military analyst is able to examine weapon system and force structure performance. Using approved measures of effectiveness the analyst makes comparisons between various weapon systems or force structures and their contribution to the combat power of the force. These combat simulations are the cornerstone of all weapon system and force structure evaluations.

There is another critical function that these high resolution simulations can play: the derivation of training development information. Examining any of the production high resolution simulation models used by the Army reveals there is much more information generated than results related only to weapon and force structure performance. One area of interest that spans all branches and functions within the Army is training information. Training information is obtainable from high resolution models and can aid significantly in training program development.

Currently TRADOC Analysis Command (TRAC) at White Sands Missile Range, New Mexico is using high resolution model output to develop realistic target arrays for the 7th Army Training Command. Through characterization of the events that take place within a series of similar simulation runs the analysts at White Sands have *characterized* tank engagements on the battlefield. Through this characterization they can describe likely target arrays and target array components. This report addresses an extension of this type of analysis by consideration of specific tasks performed by weapon system crews. Gaining insights into tasks, conditions, and standards as performed in a simulation provides valuable information for intergration into weapon system training programs.

The nature of production high resolution simulations allow for gathering specific task information throughout the battle. Through careful selection of specific task data the trainer can build *characterization of tasks* much in the same way White Sands has built characterizations of the battlefield environment. The significance of this type of analysis might be overlooked if it were not for the fact that critical training information

can now be obtained years in advance of current training development techniques. Heretofore the training developer was not able to observe operational performance of new systems until field testing of prototype systems. Production simulation runs for new systems are available years prior to field testing . In the past the training developer had to wait until the system became fully operational to see it employed in a combat environment. Through the use of high resolution simulations the training developer can *observe* the system in simulated combat and gain valuable information years prior to prototype testing and evaluation.

Although the Army has used high resolution models for many years it is hard to explain why the training developer has not taken advantage of the information generated by high resolution simulations. Administratively the trainer and combat developer have had separate organizations causing some problems in easy exchange of information. in particular emerging ideas related to uses of simulation outputs. The trainer has historically relied on observed data or subject matter expert (SME) data for development of training programs. Simulation derived data is neither observable nor viewed as operational data. Although careful examination of current production high resolution simulations reveals extremely high levels of fidelity, the training developer has habitually relied on SMEs and questionaire data gathering techniques.

The nature of current high resolution simulations allow for the recording of numerous events. history files, and their time of execution within the simulation run. History files allow the analyst to record specific actions or series of actions taken by the model throughout the course of the battle. Consideration of the simulation, not as a model. but actual combat allows the training developer to record and monitor the system's performance in *combat* from a training developer's perspective. By running a number of these battles the training developer gains insights into the character of the tasks, the conditions under which all the tasks were performed and time standards that were present in the model. If the service is using simulation data for force structure decisions and weapon system procurement decisions, it is logical to have the training developer use the conditions and standards displayed in the simulation for training development.

The training development information is very dependent upon the the accuracy and fidelity of the model. Since current models are not written to address training development issues the representation of critical training development items may not always be present. Because of the close interrelationship of system employment and

training, most training development data items are represented to some degree in good high resolution simulations. As fidelity increases and models improve there will be a similar increase in the degree of training development data obtainable from high resolution simulations.

II. METHODOLOGY AND DATA SETS

A. METHODOLOGY

The Training-Modeling Integration (T-MI) process developed at TRAC, White Sands will be used to extract the training development information from the high resolution model. The augmented T-MI process used for this report provides specific training development information for a new helicopter system, the AH-64, based upon the performance of the system in a high resolution force-on-force combat simulation. The analysis of these force-on-force battles creates an artifical *experience base* used by the training developer to characterize and define the employment of the new system. This *experience base* now allows the training developer to define specific parameters: range, number of targets viewed, target behavior, likely target combinations and engagement time lines. This type of specific information about task performance provides the training developer with the essential building blocks of the training program: TASKS, CONDITIONS, and STANDARDS.

A brief explanation of the importance of tasks, conditions and standards is needed to set the stage for their development within this thesis. Training development products include many elements; critical task lists, terminal learning objectives, lesson plans and periods of instruction (POI) are just a few of the major products. Tasks are just one of these major element and are further defined by specific conditions and standards. Specific conditions and standards for weapon system tasks form the basis of the training program's POI and establishes the framework for all training related activities. The following definitions further define these critical elements within the training development process.

- TASK--An event or activity that has a defineable starting point and is measurable.
- CONDITION--The situation or environment in which a soldier or unit is expected to accomplish a task in actual practice.
- STANDARD--A description of the performance which a unit or an individual must meet in order to demonstrate minimum acceptable performance in a task. Standards are based on the level of performance required for mission accomplishment or battlefield survival.

Table 1 depicts the flow of information and the analysis activities conducted to formulate training development information from the T-MI process. The process starts with the selection of a high resolution model and an approved scenario employing the

weapon system of interest. The simulation model is executed 20 to 40 times to produce sufficient replications of the history file to support the statistical analysis. This history file contains the event history of the battle that was fought in the simulation. In most cases the content of the history file must be decided very early in the analysis in order to insure critical activities are in fact being recorded in the history file. The postprocessors of production models will have to be programmed to capture needed event data. This recording of events or activities constitutes the indirect observations of the battlefield by the training developer. For the purposes of this report existing AH-64 history file information was used. To assist the T-MI process, an aggregation of related events and activities was conducted within the postprocessor to assist in the interpretation of the data.

Concurrent with the running of the simulations, the TRADOC proponent school is developing the initial training task lists for the new weapon system. These task lists describe the individual and collective tasks to be performed by the operators of the new system. Additionally, the SMEs on the new system are formulating their personal concepts on conditions of employment and performance standards. It is critical to formulate this reference base, task lists and SME data, for the conditions and standards; otherwise, the simulation history files are hard to interpret and relate to battle events.

Initial integration of the aggregated simulation runs, history files, and the initial task list is the first major activity of the T-MI Team. The T-MI team examines the simulation output for data items that relate to specific task performance. This analysis extracts from the history file the data base items that characterize the system events during the conduct of battle. These records of events, task histories, form the *observations* for the system operator, SMEs and the training developer.

Task history analysis is accomplished through a statistical analysis on the type, frequency, duration and character of events associated with each task. The result is a confident description of the characteristics of each task, (i.e., conditions and standards). Not all tasks listed on the individual and collective task lists will be modeled or characterized in the simulation; however, those critical point target weapon system related tasks, (i.e., main gun firing, , laser designation, missile launch constraints, etc.), will be represented and will provide the T-MI Team with data to formulate training development information. The character of the events within task histories and the resulting statistical analysis is highly dependent upon the scenario chosen for the simulation model. A variety of scenarios available in the high resolution simulation

should be run to broaden the data base for the training developer and the analyst. For institutional training base programs, multiple scenario analysis will be necessary to insure general applicability of the tasks, conditions and standards derived from the T-MI analysis.

Table 1. T-MI TRAINING DEVELOPMENT METHODOLOGY

<table>
<tr><td rowspan="2">Step 1</td><td colspan="2">A. High resolution simulation scenarios are developed for the new system, multiple scenarios desired</td></tr>
<tr><td>B1. 40 replication history file is prepared</td><td>B2. System critical task list developed</td></tr>
<tr><td rowspan="2">Step 2</td><td colspan="2">A. T-MI Team reviews history file and initial task list</td></tr>
<tr><td colspan="2">B. Task characterizations are identified by T-MI Team</td></tr>
<tr><td>Step 3</td><td colspan="2">Conduct analysis of history file data to develop characterizations for selected critical tasks</td></tr>
<tr><td rowspan="2">Step 4</td><td colspan="2">A. T-MI Team reviews statistics from the data analysis</td></tr>
<tr><td colspan="2">B. New conditions and standards are developed for initial tasks</td></tr>
</table>

B. DATA SETS

The data sets needed for the analysis are obtained from two separate agencies within TRADOC. Each set of data is critical for an effective analysis, and the analysis can not be performed if either set of data has not been fully and properly developed. A suitable high resolution production model playing the particular weapon system of interest is the cornerstone of the analysis. All statistical analysis is conducted on the history files from this high resolution model. The information obtained from the training developer is not in the form of a data file; rather it is a listing of the critical tasks essential to system operation and employment. The front end analysis is performed by the training developer to obtain the initial task list. Appendix A outlines the steps taken within a training development front end analysis (FEA). Simulation data files and the task list share equal importance in the analysis. The task list, combined with SME expertise, focuses the statistical analysis. Without proper focusing, the results of the T-MI analysis would be unrelated to the specific training requirements of the weapon system.

Through the use of these two data sets the analyst and training developer are able to relate simulated battlefield observations to real world training requirements.

1. Simulation Data

As mentioned earlier, the high resolution simulation data will be stored in a history file. The training development analyses will most likely have to use existing history files from runs of production models used for force development and weapon system acquisition purposes. Within the Army the model that has been used extensively for the last ten years is CARMONETTE. Although no longer in favor for current analyses, CARMONETTE is appropriate for use in training development analyses for fielded weapon systems. The newer high resolution model, CASTFOREM, does not have sufficient scenarios developed that play currently fielded systems. For emerging or proposed weapon system training development, CASTFOREM will be used. The data for this report was drawn from a CARMONETTE history file employing the AH-64 Apache helicopter. The scenario played in the simulation was an approved and validated scenario, used for the AH-64 and other studies. The training developer is concerned that the scenario has been approved and validated in order for the results to be integrated into the total training program for the weapon system and force. Appendix B is an outline of this specific scenario. From the T-MI analyst's perspective the critical element of this particular scenario is that it plays the weapon system of interest, AH-64, in sufficient quantity to obtain many observations of typical battlefield actions and events. This history file contains over 8800 events and actions concerning the AH-64. These 8800 events were generated by running the same CARMONETTE scenario 40 times and recording the occurrence of the same event elements.

2. Training Data

Training data is in the form of an initial task list which is an output of the FEA, the preliminary step in the development phase of the System Approach to Training

(SAT). The initial task list forms the basis for the entire planning and programming of the weapon system's training program. In the case of the AH-64 the training program included purchase of several computer driven training devices, motion simulators, an eight week institutional training program, use for two different aircraft for training and individual aviator career management. Appendix C contains the mission tasks from the initial task list used for early training development work on the AH-64.

III. ANALYSIS

This section explains and discusses the steps outlined in the methodology. The most critical aspect of the analysis process is the synthesis of the needs of the training developer with model information. The training developer's primary task is relating available simulation data to tasks, conditions and standards of the weapon system's training program. The analyst's task is to interpret the available simulation data for the training developer. Maintaining focus on the desired training development products will be the goal of all T-MI Team members.

The methodology describes each step of the analysis using representative samples. The samples used for illustrative purposes are reflective of the more difficult analytic efforts and provide insight into the underlying analytical processes and techniques used in simulation characterizations. Five tasks from the many listed on the initial task list are developed. These tasks reflect critical battlefield events and are the fundamental training requirements for the system operators. A thorough understanding of battlefield events that involve these tasks adds significantly to the training developer's ability to develop a meaningful operator training program. The number of actual tasks reflected in the high resolution model is limited by the degree of resolution in the model. As resolution increases in production simulations, more of the initial tasks will be reflected within the model.

Activities required in the methodology are grouped into steps based on logical associations. As mentioned earlier, many of the activities are conducted simultaneously by agencies with other uses for the developed information.

A. STEP 1

Table 2 lists the activity blocks in the methodology that comprise step one.

Table 2. STEP 1 ACTIVITIES

Step 1	A. High resolution simulation scenarios are developed for the new system, multiple scenarios desired	
	B1. 40 replication history file is prepared	B2. System critical task list developed

This step is characterized by each major party, the modeling community and the training community, developing their resepective initial products separately. The modelers develop appropriate scenarios for a high resolution model for the new weapon system and the trainers develop the initial task list for training. These two actions are currently required for all major weapon systems and are conducted by TRADOC proponent school organizations. At present these two activities are conducted with little interface between the two organizational elements.

Selecting a suitable simulation model with the appropriate resolution and scenarios is the first major effort in the analysis process. Early in most acquisition cycles scenario selection will be limited, but an effort must be made to gain a broad spectrum of scenarios in order to generalize the results of the training development products. The CARMONETTE model was chosen because it is the only high resolution model with approved scenarios and accessable history files for the AH-64 attack helicopter. Only one scenario is analyzed in this thesis, but others need processing and their results aggregated into the current analysis. The second critical element of Step 1 is development of the initial or critical task list for the weapon system. This document is produced by the proponent school for the weapon system and is developed using the System Approach to Training (SAT). Appendix A briefly outlines the steps and processes to develop the initial task list. This initial task list is critical to the T-MI

process because the entire analysis effort will be devoted to furthering the training developer's understanding of these tasks. Focusing on these critical tasks is a unique aspect of using the T-MI process for training development. The critical task list used in this analysis was obtained from the training developer at the U.S. Army Aviation Center and is the original task list developed in 1981 for the AH-64. The mission task listing of the task list is contained in Appendix C.

B. STEP 2

Step two is the initial effort by the T-MI Team to integrate training requirements and model information. Efforts in this step are focused on understanding the components of the tasks and the ability of the model to reflect or characterize any of these components. Task components are the conditions and standards associated with the particular task. The T-MI Team meets to determine the degree to which each task on the critical task list can be characterized within the model. Although the high resolution model portrays many events and actions of the weapon system, not all critical tasks are represented in the simulation. In this step the team identifies those tasks that are likely candidates for characterization and development. The team will not truly know if the characterizations will materialize until the data analysis begins. Candidate tasks must be selected to narrow the scope of the analysis and focus the analyst's efforts. Since the task list is long and certain tasks are much more critical than others, the training developer will prioritize those tasks requiring simulation data analysis and eliminate those tasks that can be more easily developed using other training development techniques. The tasks listed in Table 3 are the tasks that will be analyzed.

Part of the training developer's responsibility will be to educate the analyts on unique terminology. In the case of the AH-64 there are many unique terms and systems associated with the weapon system. Understanding the items described in this brief listing will aid in this analysis.

- Hellfire Modualar Missile System (HMMS)--The Hellfire missile is the primary armorment system on the AH-64. The missile is laser guided and mounts on the winglets of the AH-64. The copilot gunner is the primary crewmember to employ the HMMS.
- 30mm Chain Gun--This gun is mounted under the forward section of the aircraft and can be fired by both crewmembers. The gun is fully articulated and is used against secondary targets at close range.
- Lock On Before Launch (LOBL)--This firing mode is one of the two possible firing modes of the HMMS. In this mode the laser seeker in the missile sees the target before the missile departs the AH-64.
- Lock On After Launch (LOAL)--This firing mode is employed when the laser seeker does not see the laser designation prior to launch and acuqires the target in flight.
- Autonomous Designation--This designation technique is accomplished when the firing AH-64 laser designates his own targets. This method of designation has a higher probability of hit due to single aircraft use.
- Remote Designation--Remote designation is characterized by other than the firing AH-64 designating the target. Possible designators include other AH-64s, OH-58D aircraft and field artillery forward observers.

Table 3. **TASKS FOR ANALYSIS**

Task #6066	Search and Identify Targets
Task #6080	Engage Targets with Hellfire Missile
Task #6082	Engage Multiple Tgts w/ Two Weapons simultaneously
Task #6404	Perform LOBL Autonomous Designation Engage Procedures
Task #6405	Perform LOBL Remote Designation Engage Procedures

Selection of tasks that are represented within the model defines the scope of the analytical effort for the analyst. Through a careful review of the history files, specific data points are related to initiation, termination, frequency or other aspects of the task that the training developer feels will aid in his development of the conditions and standards. It is essential that the analyst understands what the developer needs from the characterization or the analysis will be unusable by the training developer. For the tasks selected above the essential characterizations needed are outlined in Table 4.

Table 4. TASK CHARACTERIZATIONS

Frequency of shots while in battle
Percent of shots taken in remote status
Number of targets viewed through weapon system (possible tgts)
Total shots fired in thirty minutes of battle time
Percent of hits from all shots taken
Number of multiple hits on same targets (overkills)
Expected survival time while in battle
Range to targets when hit

In addition to being keyed to the task list, the characterizations listed in Table 4 reflect several critical aspects of any battle: pace of the battle, survival function of the AH-64 and the rearm or reload requirement that is inherent to all weapon systems. Developing a training program based upon expected performance levels of the system and critical aspects of the battle will allow the trainer to emulate realistic battlefield conditions in the training environment.

C. STEP 3

Step three initiates the statistical analysis of the model output. The statistical principles are straightforward and not difficult to implement. The most difficult task is organizing the history file data and establishing the data in a easily used statistical format. The CARMONETTE simulation run data was postprocessed within the VAX mainframe at White Sands. This postprocessing collated all the engagement sequences between Red and Blue elements during each run of the simulation. For this processing only the events involving Blue helicopter elements were collated. Forty replications of the simulation were compiled to form the data base. The data base was delivered in ASCII text file format and downloaded onto the NPS IBM mainframe computer. The APL *SCRUB* function presented in Appendix D reads the ASCII file and creates a usable CMS data matrix. Once in a usable form the data was manipulated and interpreted using the APL functions listed in Appendix E. The APL functions produce vectors and statistics that describe the essential information associated with each task. GRAFSTAT is used exclusively to analyze the data. GRAFSTAT was selected because of its thorough statistical analysis package and the ease with which the graphs can be displayed within this text. Other statistical packages possess similar analysis capability and would serve equally well.

The analysis utilizes the following basic principles;

- Each of the characterizations listed in Table 4 is a random variable and insight into the behavior of these characterizations is made through development of a distribution function for each.
- The random variables described by the characterizations are describing aggregated random events that are the result of many interactions within the model. Resulting random variables are viewed as convolutions of the many random variables associated with specific events generated within the model and present good characterizations of these aggregated events.

Before examining the statistics it is desirable to develop an understanding of the nature of the distributions associated with each of these characterizations based upon real world events and actions. Not all of the distributions are intuitive nor will the fit of data be good. Selecting possible distribution functions a priori certainly provides greater confidence in distribution selection if the data fit of these distributions is acceptable. If the statistical results support intuitive distribution selection, then the conclusions will be stronger.

Each of the characterizations are examined in depth in the following paragraphs. APL functions were written to synthesize the essential data elements for each characterization. The function output, either in vector or matrix form, was then processed by GRAFSTAT. Due to the many possible GRAFSTAT options no specific reference to the GRAFSTAT function is stated. A general description of the analysis process is given and provides adequate guidance for reproduction.

1. Frequency of shots while in battle

There are a myriad of factors that impact on shot frequency. The most significant parameter impacting on shot frequency is the design of the fire control computer (FCC). Characteristics of the FCC on the AH-64 allow for three separate firing sequences: normal fire, rapid fire and ripple fire. Normal fire is when the gunner pulls the trigger and one missile is launched. Rapid fire is selection of more than one missile and one trigger pull launches all missiles at eight second intervals. Ripple fire is selection of more than one missile and one trigger pull launches missiles at one second intervals. Given a mix of normal, rapid and ripple fire shots,the expected distribution will be skewed to the left due to the likelihood of shots being fired in the one to eight second launch interval. Normal fire sequencing takes much longer than eight seconds; generally from 45 to 60 seconds. At time intervals near zero the likelihood of missile launch is zero. These characteristics, skewed to the left and passing through the origin, suggest the Gamma family of distributions. The APL function *INTSHOT* listed in

Appendix E determined the intershot times from the data base. A total of 740 time intervals were extracted and analyzed in GRAFSTAT. Total shots numbered 742, yielding 741 possible intershot times; however one intershot time was negative (a possible postprocessor error) and discarded, resulting in 740 data points. Fitting the actual intershot times to a Gamma distribution results in the graph displayed in Figure 1, along with the parameters of the distribution.

The Kolomogorov-Smirnov (K-S) Test is used to measure the goodness of fit of the sample data points to the hypothesized distribution. The K-S Test uses a comparison of the empirical cumulative distribution function with that of the hypothesized cummulative distribution function. A bound of 0.95 was set on the K-S Test and is illustrated in the figure by the dotted lines. As seen in Figure 1 the fit of the empirical data to the hypothesized distribution is quite good. Appendix F lists the numerical values for the K-S Test as performed by GRAFSTAT and additional density function information.

Listed below is the density function for the Gamma distribution.

$$f(x|\alpha,\beta) = \begin{cases} \dfrac{\beta^{\alpha}}{\Gamma(\alpha)} x^{\alpha-1} e^{-\beta x} & \text{for } x > 0 \\ 0 & \text{for } x \leq 0 \end{cases} \tag{1}$$

The parameters for this gamma distribution are:

$\alpha = .69258$

$\beta = 2.16$

A confidence interval of 95% for the Kolgomorov-Smirnov Test is shown on the graph and all sample data points fall within these bounds.

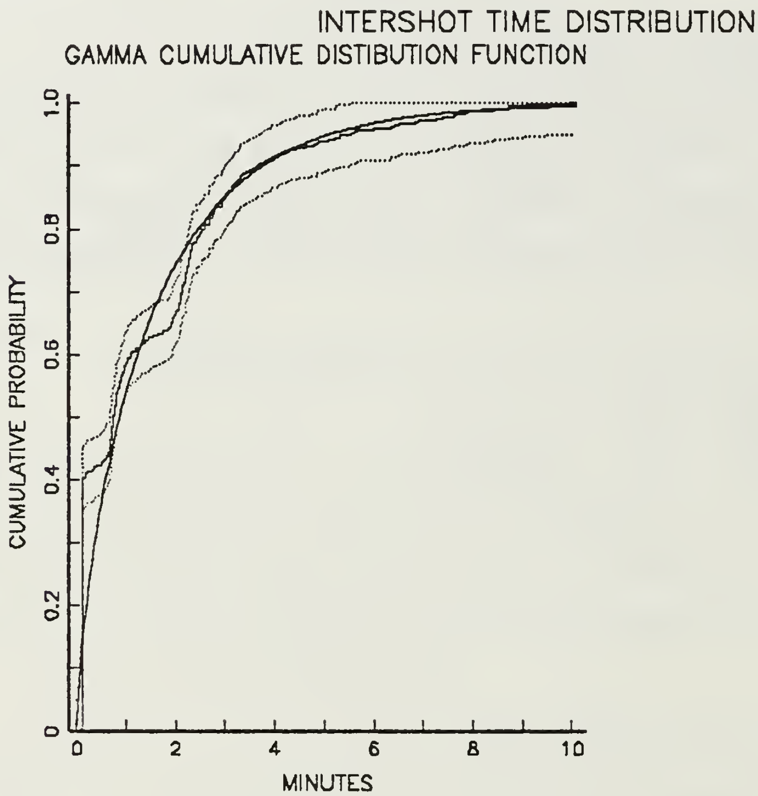

Figure 1. Intershot Distribution

2. Number of shots fired as remote shots

This information is needed to help develop the training time distribution between remote engagement training and autonomous engagement training. Remote

and autonomous firings were easily extracted from the data. The APL function *REMOTE* extracted the number of remote firings from the data matrix. In this particular scenario only the scout aircraft acted as remote designators for the AH-64's. Since only two states exist, remote and autonomous, the binomial distribution accurately represents this distribution. Selection of either remote or autonomous designation should be a fixed probability given battle conditions do not change significantly. Battle conditions and parameters are assumed to be relatively constant throughout this short intense battle. Independence between shots is also assumed because of the independent nature of the helicopter target processes. Processing targets and performing other battle tasks are related but individual target processes are assumed to be independent. A total of 742 shots were taken during the 40 replications and 119 of those shots were fired for a remote target designator. Table 5 lists the statistic and a confidence interval for the distribution parameter $\hat{p}$. A normal approximation of the binomial distribution was used to derive the confidence interval in Table 5. The 742 shots are a sufficiently large sample to justify using the normal approximation. The following equation was used to derive the confidence intervals in Table 5.

$$\hat{p} + 1.96\sqrt{\frac{\hat{p}\hat{q}}{n}} \quad \text{and} \quad \hat{p} - 1.96\sqrt{\frac{\hat{p}\hat{q}}{n}} \tag{2}$$

The binomial distribution is listed below.

$$f(x|n,p) = \begin{cases} \binom{n}{x} p^x q^{n-x} & \text{for } x = 0,1,2,\ldots,n \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

Table 5. PROBABILITY OF REMOTE DESIGNATION

Distribution	$\hat{p}$ value	95% Confidence Interval for $\hat{p}$
BINOMIAL	.16	.1336 to .1863

3. Number of targets in field of view (FOV)

Knowing the expected number of likely targets eligible for prosecution helps the trainer build realistic target arrays. Presenting battle scenarios which best represent the actual battlefield conditions allows the crews to receive representative workload experience. The values for the points plotted in Figure 2 were derived from Blue AH-64 target sensing events in all 40 replications. The APL function *FOV* created a vector listing the number of targets in the sensor's field of view each time the AH-64 conducted a target search routine. A total of 436 sensings were conducted by the AH-64's. No distributions were derived intuitively, however the distribution must be discrete and the random variable will have relatively small integer values. All discrete distributions within GRAFSTAT were fitted to the data but none achieved acceptable fits. Figure 2 is a plot of the cumulative distribution function of the data. The cumulative distribution function along with histogram derived information will be used to describe field of view characterizations.

Figure 2 shows it is quite likely to see few targets.

Pr(number of tgts $\leq$ 2.0) = .5571.

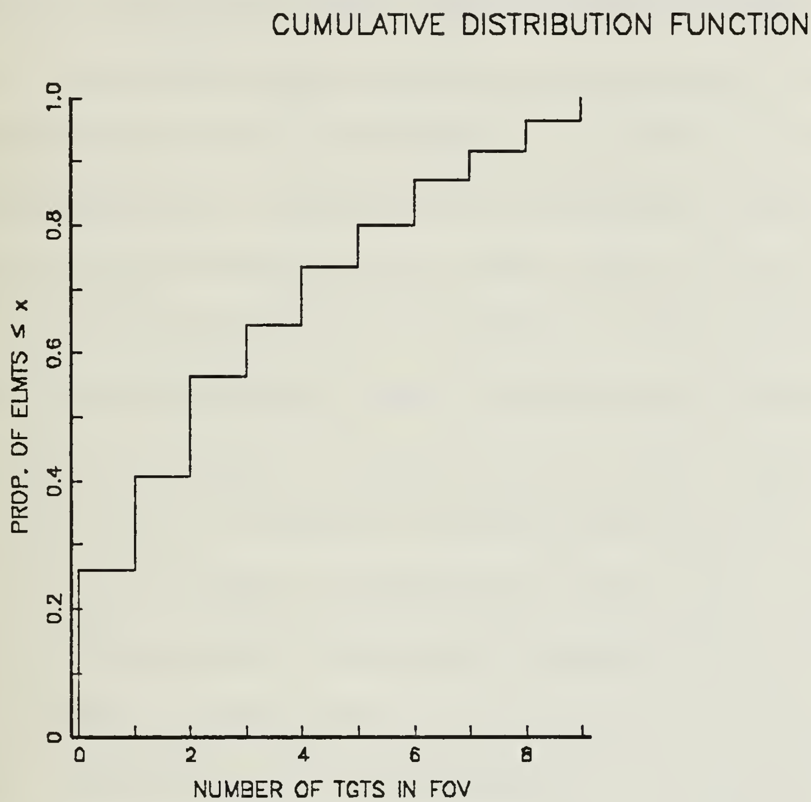

Figure 2. Number of TGTS in Field of View CDF

4. Number of shots fired in 30 minutes of battle time

This characterization is highly dependent upon the composition of the threat force and the suitability of the terrain for employment of the AH-64 aircraft. The selected scenario represents a high intensity battle with suitable terrain which yields a

large number of missile engagements. Building training scenarios around characteristics of this scenario gives realistic and intense system employment. Total shots fired and total battle time for all AH-64 systems were the values extracted from the data base. Given that battle conditions do not change, the expected number of shots fired in any given time period should be normally distributed. Assumptions required to make this conclusion are that the battle intensity is homogeneous throughout the battle, i.e., dead targets do not reduce the opportunity for engagements, and that each helicopter is fighting and firing missiles independent of the other helicopters. There are two tactical configurations for the AH-64's in this scenario; paired with scout aircraft and fighting autonomously. The paired AH-64's are fighting an independent battle but would not share the same environment with autonomous aircraft. Paired AH-64s fired primarily remotely designated targets. Only the attack configuration is addressed in Figures 3 and 4. Figure 3 shows a normal cumulative distribution function fit to the shot data. The cutoff of data points at zero would cause problems if trying to use the normal distribution in a Monte Carlo simulation for the number of shots fired. The curve fit and mean values do provide insight into the total shots fired during the simulation. Figure 4 is a fit of the same data to a gamma cumulative distribution function. The fit is acceptable but one data point, zero, was lost due to the characteristic of the gamma distribution that all x values be positive. In the case of paired AH-64 shot data, even more data points would have been lost using the gamma distribution because that data set contained numerous zero points. In the case of autonomous firings only one data point was lost in 40 replications. Since the likelihood of zero shots is small, the loss of zero as an output value when the gamma function is used is acceptable. The APL function *OVERKILL* developed a 4 X 40 matrix that lists the total shots fired in each of the 40 replications. Total shots were separated by tactical configuration, autonomous and paired, but individual aircraft firings were aggregated into the total shots for a

category. In the attack configuration, autonomous firings, three aircraft conducted the firing. As expected the intensity of firing in the two configurations was different. Appendix F lists the goodness of fit values for the K-S Test for the normal distributions as well as the gamma distribution. Additional information about the sample data set and its fit to the hypothesized distributions is also given in Appendix F.

The parameters for this normal distribution are;

$\mu = 14.275$

$\sigma = 7.946$

K-S bounds of .95 are displayed on the graph.
Graph used for information and characterizations.

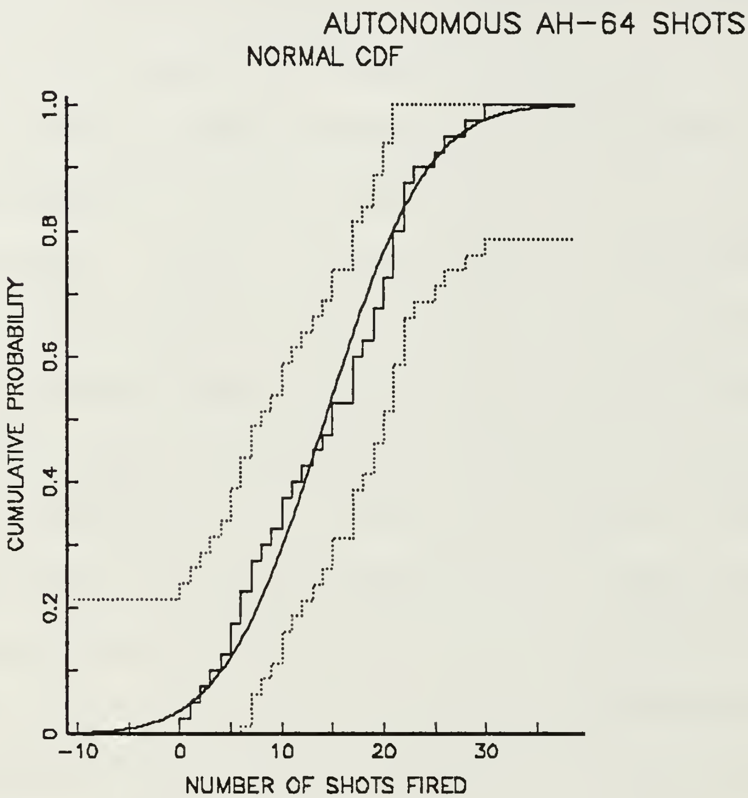

Figure 3. Number of Firings per Simulation Run (Normal)

The parameters for this gamma distribution are;

α = 2.4782

β = 5.9078

K-S bounds of .95 are displayed on the graph.

Graph used for simulations and modelling purposes.

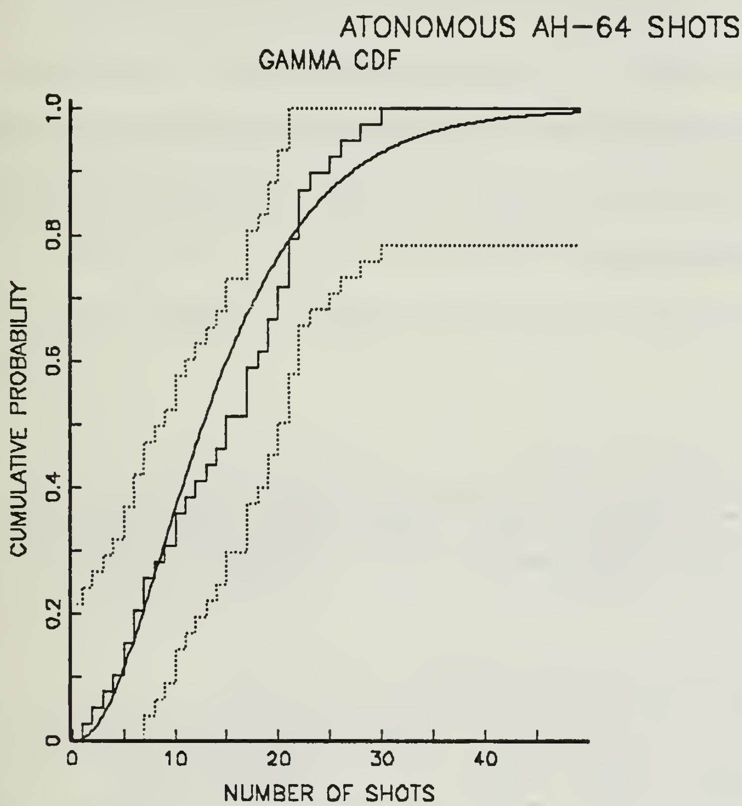

Figure 4. Number of Firings per Simulation Run (Gamma)

5. Percent of hits from all shots

Determining percent of shots that are hits aids in the establishment of standards for the gunners on live fire ranges and flight simulator exercises. The binomial

distribution is used again because the outcome of a single shot is either a hit or a miss. Using *total shot* data and *total number of hits* data the $\hat{p}$ value for this binomial distribution was determined. The APL function *OVERKILL* derived the number of hits, given a shot, for each of the shots fired. Once again, the different tactical configurations were examined. The second row of the matrix, ATTACK lists the hits for the attack aircraft and the second row in the matrix SCOUT lists the hits for the paired AH-64s. (see Appendix G for matrix data). Table 6 gives the results of the analysis. The binomial distribution is approximated by the normal distribution due to the large sample size; 571 for autonomous and 119 for remote. Equation 2 was use to compute the confidence intervals in Tables 6 and 7.

Table 6. PROBABILITY OF HIT GIVEN AUTONOMOUS SHOT

Distribution	$\hat{p}$ value	95% Confidence Interval for $\hat{p}$
BINOMIAL	.760953	.7259 to .7959

Table 7. PROBABILITY OF HIT GIVEN REMOTE SHOT

Distribution	$\hat{p}$ value	95% Confidence Interval for $\hat{p}$
BINOMIAL	.655	.5698 to .7402

6. Number of multiple hits on targets

This characterization is not directly related to a training task but does address one issue that concerns modelers and trainers alike; the realism with which the model's engagement modules portray the battlefield. Indirectly the trainer is concerned that the distributions derived are not flawed because the model is not simulating as expected. A specific concern to modelers is the number of targets that are hit more than once by the primary weapon system. Expenditure of critical missile assets on multiple hits is not

wise, given the lethality of a single hit. Multiple hits do occur but are avoided unless a second shot is needed to insure destruction. Examination of how the model treats this real world occurrence gives greater confidence in the statistical results if treated realistically or allows the trainer to modify the results and train to preclude excessive multiple hits if treated unrealistically. No obvious distributions were postulated for this random variable a priori. The only conclusions made prior to distribution fitting were that occurrences of multiple hits were expected to be small and the distribution is discrete. The APL function *OVERKILL* determined the number of multiple hits in each replication of the simulation. Only the multiple hits of the attack configured aircraft are plotted. An excellent fit was achieved, verified visually as well as with the goodness of fit test given in Appendix F. Equation 4 is the density function for the negative binomial distribution.

$$f(x|r,p) = \begin{cases} \binom{r+x-1}{x} p^r q^x & \textit{for } x = 0,1,2,\ldots, \\ 0 & \textit{otherwise.} \end{cases} \tag{4}$$

The negative binomial distribution fits well with the following parameters:

$r = 5.000$

$p = .25889$

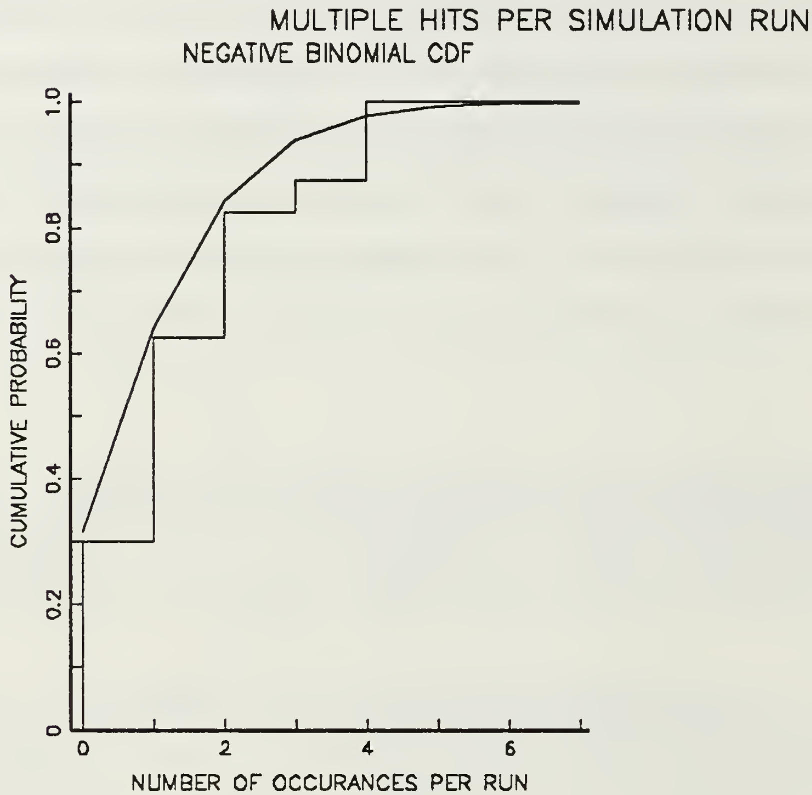

Figure 5. Number of Multiple Hits (Attack)

7. Expected survival time for single aircraft

How well does the AH-64 survive on the high intensity battlefield? Survival time is examined to answer this question and gain a broader understanding of how

hazardous is the environment for the AH-64. A review of the detailed scenario and history file showed that the helicopter battle does not start at the beginning of the simulation. The simulation starts with the Blue forces in prepared defensive positions and the Red forces initiating the attack from their starting positions. Although random, the time it takes for the helicopter battle to start is approximately seven minutes after the simulation starts.

Assume an exponentially distributed lifetime for the individual helicopter. The survival function of the individual helicopter is;

$$\bar{F}(t) = e^{-\lambda t} \tag{5}$$

This assumption is based on the following:

- The helicopters are only a fraction of the friendly forces. So the situation, as seen from the enemy's view, is a target-rich environment no matter how many helicopters have been killed. Stated in a different way, the enemy's concern is fighting the whole battle and not just engaging Blue helicopters.
- Helicopters fight in cycles of engagement and coverage; this can be described as entering and exiting the battle many times. Each entrance is independent of the previous actions. It does not matter whether the helicopter enters for the 1st or for the ith time. The assumed constant hazard rate, λ , is a weighted average of a low hazard rate in the phases of coverage and a higher hazard rate during the times of exposure. The weights themselves are dictated by battle intensity, which over the battle is assumed to be constant.

The model developed using the above assumption is one of eight items, Blue AH-64s, fighting forty independent replications. Since each replication is independent, the forty replications can be aggregated. The exponential model as postulated considers identically eight items tested for forty tests and three-hundred twenty items tested for one test. All replications end at the same time (25.0 min) but not all helicopter battles start at the same time, as shown in APPENDIX G. The helicopter battle start times are quite close, therefore the minimum start time from the forty replications was used to simplify the calculation of the parameter, $\hat{\lambda}$. The minimum start time was selected to preclude the occurrence of a negative life time should one replication produce an extremely early AH-64 kill. The lifetimes of those AH-64s that died during the conduct of each simulation run was collected and the number of survivors was recorded. This type of data is an example of Type I censored data.

a. *Maximum Likelihood Estimator*

Let t_i = battle start time to the death of the i-th AH-64 (actual lifetimes)

t_j = battle start time to the end of the simulation (censored lifetimes)

The blue helicopter's life times, t_i's are independent and identically distributed with the above stated survival function, which has the cumulative distribution function F

$$F(t, \lambda) = \begin{cases} 1 - \exp(-\lambda t) & t \geq 0 \\ 0 & otherwise \end{cases} \tag{6}$$

and the density function f.

$$f(t, \lambda) = \begin{cases} \lambda \exp(-\lambda t) & t \geq 0 \\ 0 & otherwise \end{cases} \tag{7}$$

Let

$$\underset{uncensored(d)}{t_1, t_2, \ldots, t_d,} \quad \underset{censored(n-d)}{t_{d+1}, \ldots t_n}$$

be the observed lifetimes of the helicopters. Then the MLE for the t_i is:

$$L(\lambda) = \prod_{i=1}^{d} \lambda \exp(-\lambda t_i) \prod_{j=d+1}^{n} \exp(-\lambda t_j) \tag{8}$$

Taking the natural logarithm and differentiating ln L(λ) with respect to λ results in equation 9:

$$\hat{\lambda} = \frac{d}{\sum_{i=1}^{d} t_i + \sum_{j=d+1}^{n} t_j} = .027006 \tag{9}$$

The mean survival time for the AH-64 helicopters is the reciprocal of the parameter $\hat{\lambda}$;

$$\hat{\mu} = \frac{1}{\hat{\lambda}} = 37.028 \tag{10}$$

b. *Confidence Intervals*

To approximate confidence intervals for the estimated parameter $\hat{\lambda}$, Fisher information $i(\hat{\lambda})$ was used to derive an estimate of the variance;

$$i(\hat{\lambda}) = -\frac{d^2}{d\lambda^2}\ln(\lambda) = \frac{d}{\hat{\lambda}^2} = 105{,}500 \qquad (11)$$

The upper and lower 95% confidence bound for the parameter are approximately

$$\hat{\lambda} - (1.96)\sqrt{\frac{1}{i(\hat{\lambda})}} = .020971 \quad \& \quad \hat{\lambda} + (1.96)\sqrt{\frac{1}{i(\hat{\lambda})}} = .033094 \qquad (12)$$

The reciprocals of the confidence bounds for $\hat{\lambda}$ were used to derive the confidence intervals of the estimated mean survival time.

The APL function *KILLS* was used to extract the number of aircraft killed and their death times. Another function *LAMBDA* was used to calculate the parameter, $\hat{\lambda}$. Table 8 lists the essential information of the exponential distribution that describes the expected lifetime of a single AH-64 on the battlefield.

Table 8. EXPECTED LIFETIME INFORMATION

Number of a/c Deaths, d	77
Exponential Parameter, $\hat{\lambda}$	.027006
Mean lifetime, $\hat{\mu}$	37.028
Variance Estimate, $\hat{\sigma}^2$	105,500
95% Confidence Interval	30.21 to 47.68

8. Range to targets when hit

Range data is used extensively by the training developer in almost every facet of the training program. Knowing representative target ranges facilitates correct representation of targets on live fire ranges and in simulator visual displays. Target range information significantly affects engagement time, missile time of flight and the pace of the copilot-gunner's actions. All of these aspects of target range provides for better understanding of the nature of the target engagement process. For this analysis range data provides insights into the opportunity for simulataneous engagement of targets by both the copilot-gunner and the pilot. The copilot-gunner employs the Hellfire missile system while the primary weapon system for the pilot is the 30mm chain gun mounted under the aircraft. The simulation did not simulate the 30mm gun but review of engagement ranges provides insight into the possible opportunities for its use.

The type of targets engaged by the 30mm gun is restricted to lightly skinned armor vehicles. Range data should display some normal distribution characteristics given the fact that good gunners will try and conduct most of their firing at a specified optimal range. As the battle starts and wanes the ranges should be longer and shorter, respectively. The data show a normal tendency but is slightly skewed to the left. Figure 7 displays a histogram of the ranges of lightly skinned target engagements by the Hellfire system. The 30mm gun could have been employed on targets that are less than 2500 meters. The frequency of occurrence for ranges less than 2500 meters was very small.

Equation 1 gives the distribution function for the gamma distribution. Using the cumulative distribution function for the hypothesized gamma distribution the probability of the range being less than 2500 meters is only 0.07593, calculated in GRAFSTAT.

Gamma distribution is outline by the curve overlayed on the histogram.

$\alpha = 36.837$
$\beta = 87.644$

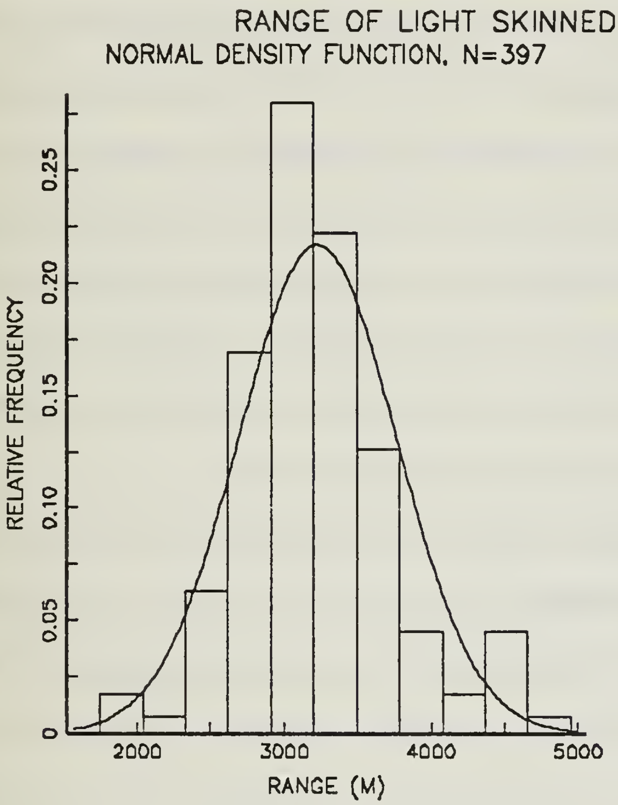

Figure 6. Range to TGTS (light) When Hit

D. STEP 4

The results of the analyses conducted in Step 3 are now related to specific training tasks. The context of this discussion will focus on the training development

requirements in preparation for operational testing of the AH-64. In the case of the AH-64, the training development work took place in 1980 with the operational test conducted May through Aug 1981. Little training development information was available in 1980. Development testing experience provided the sole source of information for operator tactical training development.

In most cases it is rather easy to relate the results of the analysis to specific training tasks. In all cases however the analytical results do contribute to greater understanding of the conditions and standards of the critical training tasks. Training information gained in this process is significant in the fact that no other quantitative training analysis information is available. The characterizations and distributional information is the only available information for the conduct of training development. All critical information relating to each specific tasks is collected on the task analysis worksheet. Appendix H presents a sample Task Analysis Worksheet for one AH-64 task.

Each of the tasks specified in Step 2 will be discussed using the information gained from the analysis. An essential element of this step is the ability of the training developer to relate the derived analytical information to practical and useful information for the training program. The SMEs are specifically looking for insights into system operation and critical information concerning system employment. A discussion of insights and critical information is presented with each task description. Information and insights not related to a specific task are discussed in the last paragraph of this section and related to the overall AH-64 system training program.

1. Task #6066: Search and Identify Targets

The results of the T-MI analysis are counter intuitive to the assumptions and conclusions made in early training development for the AH-64. In 1980 the trainers and operators of the AH-64 expected target acquisitition would be easy and the capabilities of the AH-64 acquisitition system would present very target rich displays. The

distribution described in Figure 2 is not well defined but the histogram and cumulative distribution function do present valuable information. The probability of viewing two or fewer targets in a sensing sequence is 0.5571. Trainers and operators alike expected the number of targets presented in the displays to be much higher. During the operational test it was common to find operators waiting for a multi-target display before initiating the engagement sequence. The results of the analysis indicates that if you see one or two targets, do not wait for more target rich encounters.

More important to the task of training is the knowledge that now the training developer has good reason to develop training programs that present target arrays with specific numbers of threat vehicles. The histogram is used to develop specific numbers of targets for simulator and live fire gunnery exercises. Cumulative distribution function characteristics are used in a Monte Carlo process to generate the number of targets viewed. This information is used directly in the development of the conditions for this task. This task is the initial step in the target engagement cycle and is a fundamental skill that significantly impacts on total system effectiveness.

2. Task #6080: Engage Targets with Hellfire Missile

This task is the most critical activity for the weapon system. Most of the characterizations developed relate to this task. The distribution in Figure 1 describes the intershot time for the copilot-gunner. The mean of this distribution, 1.4 minutes, can be interpreted as measuring the firing intensity expected from a trained copilot-gunner. Training programs should develop operators to employ the Hellfire system at a similar pace. The number of shots fired in 30 minutes of battle is derived using equation 13. The battle time for each simulation displayed little variance, 0.3, with an average time of 16.576 minutes. Using battle time information and the mean number of shots from the hypothesized distribution in Figure 4 resulted in 9.06 shots per 30 minutes of battle time for each AH-64..

$$Shots\ in\ 30\ \text{min} = \frac{30\ \text{min}}{average\ simulation\ ti.} \times \frac{distribution\ mean}{aircraft\ number} = 9.06 \qquad (13)$$

Thirty minutes was chosen as a maximum time for intensive training periods. When computing the expected number of shots for a single aircraft, the mean of the distribution was divided by the number of aircraft functioning in that mode/configuration. The assumption that battle conditions do not change for 30 minutes allows extrapolation of the total shot count.

Probability of hit information outlined in Tables 6 and 7 are additional standards that would be incorporated into gunnery exercises for the AH-64. Copilot gunners have a quantified standard to meet in their gunnery training. In 1981 there was no standard for timely sequencing of shots during training. During operational testing crews were faced with multi-target opportunities and were unable to capitalize on the system's capability due to slow system engagement. There were no standards developed for the speed or frequency with which targets were to be engaged prior to the operational test. The intershot interval and total number of shots per aircraft for 30 minutes of battle give good practical insight into the intensity of Hellfire engagements. The single biggest weakness of the operational test crews was their inability to quickly and properly engage targets.

3. Task #6082: Engage Multiple Tgts w/ Two Weapons Simultaneously

Target range data give insights into possible simultaneous engagement opportunities. From Figure 7 it can be seen that there are few light targets at ranges less than 2500 meters. This does present usable information to the training developer because quantitative rational is established to distribute training time between single weapon engagement and simultaneous engagement. The sample data shows ten to eleven percent of lightly skinned targets are within range. This is even a smaller

percentage of the total target population. This training task needs to be addressed in the training program, but little accommodation and time should be expended.

In preparing for the operational test, equal classroom time was allotted to all modes of fire. Simultaneous engagement was practiced and was expected during the conduct of the operational test. Results of the operational test, however, agree with the simulation results that none occurred unless specifically staged.

4. Task #6404: Perform LOBL Autonomous Designation Engage Procedures

Table 3 provides information to the training developer on the proportion of time the AH-64 was used in the autonomous firing mode. Training programs should reflect proportional time allotments for remote designation training and autonomous firing training. Proper allocation of training time to most likely modes of operation improves training effectiveness. Approximately 85% of the engagement training time should be devoted to autonomous engagements.

Engagement training training time was not proportioned in this way for the operational test training. Both engagement modes received equal emphasis although crews did prefer autonomous shots.

5. Task #6405: Perform LOBL Remote Designation Engage Procedures

Table 3 provides the same information as in Task #6404. Approximately 15% of engagement training should be devoted to remote engagements. This information is also useful for input into the OH-58D (the primary remote designator) training development effort.

6. Additional Information

Figure 5 presents information used to validate the output of the simulation. Confidence in the simulation's ability to represent real world engagement sequencing gives greater confidence in the T-M1 results. A characteristic of the Hellfire missile is that is produces a tremendous fire ball upon target hit. So tremendous is the fire and

explosion that it would not be missed by combatants. The low incidence of multiple hits is realistic, given the nature of the weapon system. Multiple hits may occur when two missiles are launched at the same target within the time of flight for the shorter range missile. The low incidence of multiple hits, mean value 1.375, gives confidence in the model's ability to portray realistic engagements.

Table 8 provides another observation of the general nature of the battlefield. The survivability data in Table 8, coupled with the intershot and total shot data, gives the aviation unit insights into the intensity of this particular battle scenario. This scenario is very intense and provides realistic information for the aviation unit to use in its maintenance, rearming and support planning. This information validates the survivability of the AH-64 in a high intensity battle. Crew confidence in the system's ability to fight and survive is an integral part of the training program.

IV. CONCLUSIONS

A. METHODOLOGY

The T-MI process used in this thesis is a straightforward application of standard data analysis techniques. The element that makes this application of data analysis techniques unique is its integration of training development requirements and analytical techniques. The *characterization* is the unique aspect of the methodology that integrates the training developer and the analyst. Traditionally, the trainer has looked to observable data for his training development information. Now, using surrogate observations via the simulation, he is able to view battlefield system employment and operation.

The characterizations selected in the above analysis are not unique nor are the analytical techniques selected for describing the characterizations. The particular analytical method or technique is not important; what is critical is that the process provides the necessary information to the training developer. The methods and techniques addressed in this thesis demonstrate the objectives and mechanics of the methodology.

This methodology is applicable to any weapon system that has high resolution simulation models available for analysis. Examples focused on emerging systems early in the acquisitition cycle but the methodology is equally applicable to fielded systems needing training effectiveness analysis or training review. Systems that undergo significant modifications and justify new training development efforts also are prime candidates for T-MI analysis. The cost of training today often justifies review of current training programs and T-MI input into the review process is an additional tool to insure training programs address real world training requirements.

B. APPLICATIONS

Application of the T-MI process covers every aspect of training. T-MI analysis produces information which in many cases is not available or is extremely expensive to acquire.

1. Training Development for Operational Testing

References throughout this thesis address the application of the T-MI process to the training development of an emerging system. In the case of the AH-64 the information produced would have been valuable to the operational test training program. The AH-64 was a system that differed significantly from then currently fielded systems. No suitable experience base existed to provide a basis for departure in the development of conditions and standards for AH-64 tasks. The T-MI process provides a distinct improvement in task information when SME and traditional data bases are lacking good task information. Another unique feature of T-MI information is that it is available as soon as the high resolution model has been verified and validated, which is several years before the system is operational.

2. Simulator and Procedural Trainer Scenario Design

New major weapon systems are requiring extensive use of simulators and procedural trainers. Training devices such as simulators and procedural trainers need representative, authentic and challenging displays and scenarios. Using distributions developed from the T-MI process, the trainer can recreate key battle parameters and events in the training devices. Various target arrays and event sequencing can be accomplished through use of a Monte Carlo process using the probability distributions of the specific battlefield event. When randomness is based upon known distributions of battle parameters the training devices become more effective and truly complement the overall training program.

3. Training Program Review and Training Effectiveness Analysis

Fielded systems experiencing training difficulties or systems undergoing programmed review can use the T-MI process to evaluate current training programs. In this particular application current training information is compared to the results of the T-MI analysis. New insights into system operation may result in improved training techniques and system performance.

4. Evaluation of High Resolution Simulation Modules

Characterizing the behavior of the weapon system in the high resolution model allows the training community to verify system operation as represented in the simulation modules. A thorough understanding of the characteristic behavior of the weapon system in the simulation instills confidence in the simulation results. New weapon systems are very dependent upon effective man-machine interface and an effective training program. Operator input must be quantifiable and within the limits of the target population. Characterizations of task events quantify operator requirements. Should operator requirements as simulated in a weapon system simulation module exceed operator capabilities, then the simulation module must be modified to achieve realistic output. This application of the T-MI process takes place very early in the weapon system life cycle during the simulation development process.

5. Operator performance evaluation

Applications of this methodology to training development are demonstrated, but an equally fruitful application is in the area of operator performance evaluation. The capability to use this process for real time performance evaluation is a result of ongoing activities within TRADOC. Training commands have and are developing instrumented range facilities for hardware testing and unit training evaluations. To date these facilities have focused on the evaluation and performance of hardware, tactics and doctrine. Hardware evaluation is best defined through operational testing.

Instrumented range facilities provide the capability to conduct quantitative operational testing. Operator performance during operational testing has become an issue in recent major operational tests. The T-MI methodology provides a quantitative characterization of system and operator behavior during test trials. Instrumented range data is similar to data obtainable from high resolution models. Using the T-MI process as if the trial data were simulation data gives the trainer the ability to characterize system and operator behavior relative to specific tasks. The focus of the T-MI process is on task characterizations and these characterizations give insights into operator and system performance. Figure 1 characterizes intershot time for the simulation; if used in performance evaluation it would characterize specific operator intershot times. Individual crews can be evaluated or aggregate crew performance can be assessed. This type of analysis sheds light on tasks needing additional training should system performance levels fall below expected standards.

C. RECOMMENDATIONS

The training community must make use of every available source for training development information. New weapon systems demand the utmost from the operator, and the trainer is faced with developing the training program early to insure procurement of needed facilities and devices. The T-MI process uses available information and personnel to extract valuable information from production high resolution simulations. It should be used early in the acquisition cycle to verify simulation output and then used continuously for training development. As updated simulations provide better representations of weapon systems and the battlefield continued application will help insure the training developer has the best available information. Training development challenges are tough, but through effective applications of quantitative analysis the trainer can keep pace with technology and the threat.

APPENDIX A. SYSTEMS APPROACH TO TRAINING

A. INTRODUCTION

This appendix outlines the critical steps in the System Approach to Training (SAT) as they deal with the TM-I process. TRADOC Regulation 350-7 thoroughly describes and explains the use of SAT. The following paragraphs are taken directly from the regulation.

The concept of a systems approach to training is based on an overall view of the training process. It is characterized by an orderly process for gathering and analyzing collective and individual performance requirements, and by the ability to respond to identified needs. The systems approach ensures the development of training which builds upon operational concepts, the force structure and the characteristics of new weapons and systems designed for strategic missions and the evolving threat.

B. THE PROCESS

SAT uses five distinct processsess in its development of training and training related products. The five processes are briefly outlined in this paragraph.

- Evaluate. The term evaluate is used in the general judgmental sense of the continuous monitoring of a program or of the training function as a whole and involves both verification and validation. The process consists of internally evaluating the training program during each phase of its preparation while concurrently externally evaluating the overall training function.

- Analyze. The process of analysis must include an extensive examination of the threat, doctrine, organization, geographical locations of units, resources constraints, type of units, new sytems, and associated collective tasks. Examination of the collective tasks leads to identification of the individual tasks that must be performed to achieve combat readiness.

- Design. The purpose of design is to ensure the subsequent systematic development of training programs and training support materials that enhance the overall efficiency and effectiveness of the total training system. The process is driven by the products of analysis and terminates in a blueprint of the training programs for subsequent development.

- Develop. This process elaborates and supplements the products of design and results in training programs ready for implementation and training support materials ready for use.
- Implement. The implementation process involves the separate but related functions of preparing for and conducting training.

C. FRONT END ANALYSIS (FEA)

The FEA is the initial process for any newly started training development effort. It comprises the bulk of the work effort within the analysis phase of the SAT methodology.

- The FEA employs a top down approach, beginning with the Battlefield Development Plan and the threat analysis, the unit table of organization (TOE), and the applicable doctrine publications to determine the unit missions.
- Unit missions are the primary tasks which the unit was orgainized and equipped to execute. The anlayst examines the TOE and the doctrinal publications to determine the answer to the question "Why does this unit exist?" The answer to that question is the type-unit mission list.
- Mission are further broken down into collective tasks. All tasks identified are categorized as critical, essential or other. Critical tasks are those tasks necessary to accomplish a unit's combat mission. Essential tasks are those necessary to accomplish a unit's peacetime or administrative support mission.
- The initial missions and collective tasks must be examined by subject matter experts (SME) and units in the field must be consulted. This is because the determination of WHAT must be done raises the issues of HOW it must be done, and HOW WELL it must be done.
- The results of the analysts must be screened against the selection criteria in order to ensure that the selected mission, collective tasks, and leader and individual tasks are limited to those essential for accomplishing the unit's true purpose or ensuring its wartime success.

APPENDIX B. SIMULATION SCENARIO

A. INTRODUCTION

This scenario depicted an Armor Task Force defending against an attacking Soviet Tank Regiment. It was based on TRADOC Standard Scenario, Europe V, and an existing scenario which was used for study at TRAC-WSMR. The combat situation was based on Critical Incident (CI) #4, of the Europe V Gaming Report.

B. GENERAL SITUATION

The scenario was set in V (US) Corp. A BLUE Armd Div and an ACR (+) defending forward while a BLUE In Div (Mech) (+) and an In Div (-) were in reserve. The BLUE Armd Div had completed its covering force fight and conducted a passage of lines through MBA units. Covering forces in that sector were highly successful in stopping the advance of RED Guards Tank Div (GTD) 1st echelon regiments which then began assumming hasty defensive positions. In the BLUE ACR (+) sector, the regiment deployed two Cav squadrons and a RAS forward to act as covering forces. The threat, a Motorized Rifle Division (MRD), attacked with two motorized rifle regiments (MRR) in the first echelon. The BLUE covering forces fought back to prepared positions where they would defend in sector with a BLUE TF (M) in the north, a Cav squadron in the center, and a second Cav squadron in the south. The BLUE RAS conducted economy of force operations south of the second squadron while a BLUE TF (A) was regimental reserve. (See Europe V, volume 1, V (US) Corps Operational Scenario and Europe V, volume 1, V (US) Corps Gaming Report, Critical Incidents 1 through 9).

While the BLUE Armd Div was very successful in defeating the first echelon regiments of the RED GTD during the covering force fight, the BLUE ACR (+) was forced from successive positions more quickly than anticipated. This occurred because the first Cav squadron took the brunt of the attack by two regiments and was severely attrited. The regimental commander moved the regimental reserve, BLUE TF (A), forward to MBA defensive positions which the first Cav squadron was to occupy. The first Cav squadron passed through the BLUE TF (A) and reconstituted as the regimental reserve. The threat, seeing that excellent progress was made, ordered the RED MRR to keep enemy forces fixed in the north and the second MRR to continue its advance south-southwest to expand the zone. The RED Tank Regiment (TR) was committed

to complete the destruction of enemy forces to the division front to the extent that a second echelon division could subsequently conduct exploitation operations.

This scenario portrays the RED TR attack. The BLUE TF (A) was committed in stages. During CI #3, along with two troops of the second Cav squadron, one company of BLUE TF (A) was ordered into the first Cav squadron's sector but arrived too late to stop the advancing first echelon regiments of the MRD. The regimental commander determined that his BLUE TF (A) would not be able to occupy the planned postion of the first Cav squadron because of the rapid rate of advance of the RED MRD. He ordered the BLUE TF (M) to continue to defend in the north and the second Cav squadron to continue to defend in the south. The BLUE TF (A) occupied a blocking positon between and to the rear of the BLUE TF (M) and the second Cav squadron. The regiment permitted a shallow penetration to occur between BLUE TF (M) and second Cav squadron. BLUE TD (A) blocked the head of the penetration and BLUE Attack Helicopter Battalion (ATKHB) counterattacked on the flanks of the MRD penetration.

The commander of BLUE TF (M) had a battle position prepared and gave BLUE Co (TF reserve) the operations order mission to occupy this battle position. This position defended the avenue of approach that threatened the southern flank of BLUE TF (M). The scout platoon of BLUE TF (M) screened the southern flank of the TF. The regimental commander ordered BLUE ATKHB to provide early warning to the TF (M) in the event that any enemy forces turned north toward the TF (M) sector. The second RED MRR in its attack southwest was not positioned where its forces could influence the southern attack helicopter company.

The first echelon regiments of the RED MRD continued to open the shoulders of the penetration. The first RED MRR established a hasty defense in the north and fixed BLUE TF (M). The second RED MRR attacked south-southwest into the sector of the second BLUE Cav squadron to expand the zone. The RED TR, a second echelon regiment of RED MRD, was committed through the first MRR and second MRR to continue the attack. The BLUE TF (A) occupied a blocking position along the axis of advance of the RED TR.

C. MODELING CONSIDERATIONS

In order to transition from Europe V to this high resolution scenario, certain assumptions, modifications, and extrapolations from Europe V were necessary. The location of the battle was moved from its location in Europe V to take advantage of

available digitized terrain. This scenario focused on the battle during the BLUE ATKHB counterattack. Only the forces that impacted on this portion of the battle were actually modeled. These forces consisted of the two northern companies of BLUE TF (A) (Tm C and Tm D) and the first echelon battalions of the RED TR (1st, 2d and 3d tank battalion). Also modeled were the air defense, artillery and aviation assets that impacted on this portion of the battle.

At the start of the war game, Tm C and Tm D of BLUE TF (A) occupied their battle positions, BLUE ATKHB moved into position to conduct their counterattack, and RED TR attacked with its first echelon tank battalions on three seperate routes. The lead elements of these tank battalions were 5-km away from Tm C at the start of the battle.

D. COMPOSTION OF FORCES

The BLUE force structure was the Army of Excellence, with equipment updated to 1995 and updated air defense weapons (FOG-M, ADDATS) in accordance with the forward Area Air Defense Study.

BLUE Systems.

Type	Number
M1A1	16
M2	12
ITV	4
M109A3	16 (No. of tubes)
M110A2	8 (No. of tubes)
MLRS	1 (No. of tubes)
M106A2	6
OH-58D	3
AH-64	5
A-10	4
ADATS	4
FOG-M	2
FAAO	1

RED Systems.

Type	Number
FST II MFT	93
BMP-F	42
122mm SP How	24 (No. of tubes)
152mm SP How	87 (No. of tubes)
152mm SP Gun	22 (No. of tubes)
VASILIK mortar	8
HAVOC	8
HAVOC-2 (air-to air)	4
FROGFOOT	4
FULCRUM	6
SA-14	6
ZSU-X	4
SA-X-15	6
SA-13	4

APPENDIX C. SAMPLE AH-64 TASK LIST

A. MISSION TASK LIST

The task list shown in this appendix is only a listing of the mission tasks for the AH-64 as developed in 17 Dec 1982. There are a total of 213 training tasks for the AH-64 but only the 27 *mission tasks* are listed because they best relate to the use of the TM-1 process.

B. MISSION TASK LIST

Task Number	Task Description
6025	Call for/Adjust Indirect Fire
6064	Select and Occupy Firing Position
6066	Search and Identify Targets
6079	Select Appropriate Weapon System
6080	Engage Target with Hellfire Missile
6081	Engage Target with 30mm Gun
6082	Engage Targets w/ two Weapon Systems Simultaneously
6083	Search, Acquire, Recognize, and Identify Targets with Day Television
6084	Search, Acquire, Recognize, and Identify Targets with the Forward Looking Infra-Red
6085	Search, Acquire, Recognize, and Identify Targets with the Direct View Optics
6086	Perform Target Tracking
6087	Perform Target Handoff Procedures
6088	Operate Onboard Recording System
6101	Engage Target with 2.27 FFAR
6202	Operate the AWS-Pilot
6203	Operate the AWS-Copilot
6302	Operate the ARCS-Pilot
6303	Operate the ARCS-Copilot
6304	Perform Initilization of ARCS Control Plan
6402	Perform Weapons Arming Procedures
6403	Perform PTWS Initialization Procedures
6404	Perform LOBL Autonomous Designation Engagement Procedures
6405	Perform LOBL Remote Designation Engagement Procedures
6406	Perform LOBL Ripple Fire Engagement Procedure
6407	Perform LOAL Autonomous Designation Engagement Procedures
6408	Perform LOAL Remote Designation Engagement Procedures
6409	Perfrom LOAL Ripple Fire Engagement Procedure

APPENDIX D. FUNCTION FOR CLEANING DATA

The APL function SCRUB listed in this appendix was used to clean the data file obtained from the VAX postprocessor. The major tasks conducted within SCRUB is cleaning and organizing. The most critical function performed by SCRUB is construction of the matrices, SHOT1, SHOT2, SHOT3 and SHOT4. SCRUB must be run seperately for each of the four shot data sets. Workspace size limitations precluded aggregation.

```
      ∇ SCRUB
[1]     SHAPE1←ρSHOT3
[2]     A←SHOT3=' '
[3]     SPACES←(ρA)ρ(∧/[1] A)
[4]     COMSHAPE←((ρSPACES)[1]),(ρSPACES)[2]-+/SPACES[1;]
[5]     COMPACT←COMSHAPEρ(,~SPACES)/(,SHOT3)
[6]     B←,COMPACT=' '
[7]     COMPACT←,COMPACT
[8]     COMPACT[B/ι(×/ρB)]←'0'
[9]     SHOT3←(ρSHOT3)ρ(,~SPACES)\COMPACT
[10]    SHOT3[;42,50,51,53,79,87,113,114,115,116]←' '
[11]    SHOT3[((SHOT3[;52]='E')/ι(1↑SHAPE1));52]←'1'
[12]    SHOT3[((SHOT3[;52]='L')/ι(1↑SHAPE1));52]←'2'
[13]    SHOT3[((SHOT3[;52]='I')/ι(1↑SHAPE1));52]←'3'
[14]    SHOT3[((SHOT3[;52]='M')/ι(1↑SHAPE1));52]←'4'
[15]
[16]    SHOT3[((SHOT3[;52]='C')/ι(1↑SHAPE1));52]←'5'
[17]    SHOT3[((SHOT3[;52]='H')/ι(1↑SHAPE1));52]←'6'
[18]    SHOT3[((SHOT3[;107]='M')/ι(1↑SHAPE1));107]←'1'
[19]    SHOT3[((SHOT3[;107]='K')/ι(1↑SHAPE1));107]←'2'
[20]    SHOT3[((SHOT3[;107]='O')/ι(1↑SHAPE1));107]←'3'
[21]    SHOT3[((SHOT3[;107]='F')/ι(1↑SHAPE1));107]←'4'
[22]    SHOT3[((SHOT3[;107]='D')/ι(1↑SHAPE1));107]←'5'
[23]    SHOT3[((SHOT3[;107]='H')/ι(1↑SHAPE1));107]←'6'
[24]    SHOT3[((SHOT3[;108]≠'0')/ι(1↑SHAPE1));108]←'0'
[25]    SHOT3[((SHOT3[;109]≠'0')/ι(1↑SHAPE1));109]←'0'
[26]    SHOT3[((SHOT3[;110]≠'0')/ι(1↑SHAPE1));110]←'0'
[27]    SHOT3[((SHOT3[;111]≠'0')/ι(1↑SHAPE1));111]←'0'
```

APPENDIX E. GENERAL APL FUNCTION LISTING

The APL functions listed in this appendix were used to compile and extracted need data from the simulation history file. These functions worked directly with the large 8812 X 19 matrix as well as with resultant vectors and matrices from other functions. The output values of these functions were the only informaion used in the statistical analysis.

```
      ∇ TIMES←BATTIM;Y;Z;Y5;Z5;ST;TI6;Y6;Y7;Y8;Y9;
      Z6;Z7;Z8;Z9;TI5;TI7;TI8;TI9
[1]   ZT←0
[2]   TI5←0
[3]   TI6←0
[4]   TI7←0
[5]   TI8←0
[6]   TI9←0
[7]   A←1
[8]  L:Y←DATA[;1]=A
[9]   Z←Y/[1] DATA
[10]  ST←Z[1;5]
[11]  ZT←ZT,ST
[12]  Y5←(Z[;6]=1)∧(Z[;7]=105)
[13]  Y6←(Z[;6]=1)∧(Z[;7]=106)
[14]  Y7←(Z[;6]=1)∧(Z[;7]=107)
[15]  Y8←(Z[;6]=1)∧(Z[;7]=108)
[16]  Y9←(Z[;6]=1)∧(Z[;7]=109)
[17]  Z5←Y5/[1] Z
[18]  Z6←Y6/[1] Z
[19]  Z7←Y7/[1] Z
[20]  Z8←Y8/[1] Z
[21]  Z9←Y9/[1] Z
[22]  TI5←TI5,((((1↑ρZ5)-1)↓Z5[;5])-ST)
[23]  TI6←TI6,((((1↑ρZ6)-1)↓Z6[;5])-ST)
[24]  TI7←TI7,((((1↑ρZ7)-1)↓Z7[;5])-ST)
[25]  TI8←TI8,((((1↑ρZ8)-1)↓Z8[;5])-ST)
[26]  TI9←TI9,((((1↑ρZ9)-1)↓Z9[;5])-ST)
[27]  A←A+1
[28]  TIMES←(+/TI5),(+/TI6),(+/TI7),(+/TI8),(+/TI9)
[29]  →L×(A<41)


      ∇ DISPL
[1]   Y5←(DATA[;6]=1)∧(DATA[;7]=105)∧(DATA[;10]=3)
```

```
[2]    Y6←(DATA[;6]=1)∧(DATA[;7]=106)∧(DATA[;10]=3)
[3]    Y7←(DATA[;6]=1)∧(DATA[;7]=107)∧(DATA[;10]=3)
[4]    Y8←(DATA[;6]=1)∧(DATA[;7]=108)∧(DATA[;10]=3)
[5]    Y9←(DATA[;6]=1)∧(DATA[;7]=109)∧(DATA[;10]=3)
[6]    Z5←Y5/[1] DATA
[7]    Z6←Y6/[1] DATA
[8]    Z7←Y7/[1] DATA
[9]    Z8←Y8/[1] DATA
[10]   Z9←Y9/[1] DATA
[11]   DIST←0
[12]   A←1
[13]  L:Y←Z5[;1]=A
[14]   X←Y/[1] Z5
[15]   GRID1←X[;5,8,9]
[16]   GRID2←(ρGRID1)ρ(((1↓(ρGRID1))↓,GRID1),(,(GRID1[(1↑ρGRID1);])))
[17]   DIS←(((GRID1[;2]-GRID2[;2])*2)+((GRID1[;3]-GRID2[;3])*2))*0.5
[18]   DIST←DIST,DIS
[19]   A←A+1
[20]   →L×(41≥A)


       ∇ DIST;Y;Z;X1;X2;Y1;Y2
[1]    Y←(DATA[;6]=1)∧(DATA[;10]=4)∧(DATA[;13]>43)∧(DATA[;11]<130)
[2]    Z←Y/[1] DATA
[3]    X1←Z[;8]
[4]    Y1←Z[;9]
[5]    X2←Z[;14]
[6]    Y2←Z[;15]
[7]    DIS←(((X1-X2)*2)+((Y1-Y2)*2))*0.5


       ∇ FOV;Y;Z;Z1
[1]    Y←(DATA[;6]=1)∧(DATA[;10]=1)
[2]    Z←Y/[1] DATA
[3]    Y←(Z[;7]=101)∨(Z[;7]=102)∨(Z[;7]=103)
[4]    Z1←Y/[1] Z
[5]    SCT←Z1[;19]
[6]    ⎕←ρSCT
[7]    NUMSCT←+/Z1[;19]
[8]    Y←(Z[;7]=105)∨(Z[;7]=106)∨(Z[;7]=107)
       -(Z-;7-=108)-(Z-;7-=109)
[9]    Z1←Y/[1] Z
[10]   ATK←Z1[;19]
[11]   ⎕←ρATK
[12]   NUMATK←+/Z1[;19]


       ∇ INTSHOT;Y6;Y7;Y8;Y9;Z6;Z7;Z8;Z9;X;Y
[1]    Y5←(DATA[;6]=1)∧(DATA[;7]=105)∧(DATA[;10]=3)
```

```
[2]    Y6←(DATA[;6]=1)∧(DATA[;7]=106)∧(DATA[;10]=3)
[3]    Y7←(DATA[;6]=1)∧(DATA[;7]=107)∧(DATA[;10]=3)
[4]    Y8←(DATA[;6]=1)∧(DATA[;7]=108)∧(DATA[;10]=3)
[5]    Y9←(DATA[;6]=1)∧(DATA[;7]=109)∧(DATA[;10]=3)
[6]    Z5←Y5/[1] DATA
[7]    Z6←Y6/[1] DATA
[8]    Z7←Y7/[1] DATA
[9]    Z8←Y8/[1] DATA
[10]   Z9←Y9/[1] DATA
[11]   TIME←0
[12]   A←1
[13]  L:Y←Z5[;1]=A
[14]   X←Y/[1] Z5
[15]   X←X[;5]
[16]   X1←1↓X,25
[17]   Y←X1-X
[18]   REC←(⍴Y-1)↑Y
[19]   TIME←TIME,REC
[20]   A←A+1
[21]   →L×(41≥A+1)
[22]   TIME5←TIME[⍋TIME]


       ∇ KILLS;YY;Z;START;Y
[1]    A←1
[2]    KILLTI←⍳0
[3]    ST←⍳0
[4]   L:YY←(DATA[;1]=A)
[5]    Z←YY/[1] DATA
[6]    START←Z[1;5]
[7]    Y←(Z[;7]=105∨Z[;7]=106∨Z[;7]=107∨Z[;7]=108∨Z[;7]=109)
[8]    Y1←(Z[;6]=1)∧(Z[;19]=200000)
[9]    Y←Y∧Y1
[10]   KITI←Y/[1] Z
[11]   KILTI←KITI[;5]
[12]   KILLTI←KILLTI,KILTI
[13]   A←A+1
[14]   ST←ST,START
[15]   →L×(A≤41)


       ∇ LAMBDA;D
[1]    D←⍴KILLTI
[2]    SUMTI←+/(KILLTI-(MEAN STARTI))
[3]    SUMTJ←(200-⍴KILLTI)×((MEAN STOPTI)-(MEAN STARTI))
[4]    LAM←D÷(SUMTI+SUMTJ)


       ∇ OVERKILL;Y;Z;YY;ZZ;X;A;ZZZ;HK;OVR;XX;
```

```
      OVER;SHOTS;HKSH;OTH;Y1;SIZE
[1]   OVER←⍳0
[2]   SHOTS←⍳0
[3]   HKSH←⍳0
[4]   OTH←⍳0
[5]   A←1
[6]   Y←((DATA[;19]=200000)∨(DATA[;19]=600000)∨(DATA[;19]=500000))
[7]   Y1A←(DATA[;19]=100000)∨(DAT[;19]=300000)∨(DAT[;19]=400000)
[8]   Y1B←DATA[;6]=1
[9]   Y←(Y∨Y1A)∧Y1B
[10] ⍝Y1←(DATA[;6]=1)∧((DATA[;7]=102)∨(DATA[;7]=103)∨(DATA[;7]=101))
[11] ⍝Y1←(DATA[;6]=1)∧((DATA[;7]=105)∨(DATA[;7]=109))
[12] ⍝Y1←(DATA[;6]=1)∧((DATA[;7]=106)∨(DATA[;7]=107)∨(DATA[;7]=108))
[13] ⍝Y←Y∧Y1
[14]  Z←Y/[1] DATA
[15] L:YY←Z[;1]=A
[16]  SHOTS←SHOTS,+/YY
[17]  ZZ←YY/[1] Z
[18]  HK←(ZZ[;19]=200000)∨(ZZ[;19]=600000)
[19]  HKSH←HKSH,(+/HK)
[20]  ZZZ←HK/[1] ZZ
[21]  OTH←OTH,(+/(~HK))
[22]  X←ZZZ[;13]
[23]  SIZE←(⍴X)
[24]  XX←((X⍳X)=⍳⍴X)/X
[25]  OVR←SIZE-⍴XX
[26]  OVER←OVER,OVR
[27]  A←A+1
[28]  RESULT←((SHOTS,[0.5] HKSH),[1] OVER),[1] OTH
[29] ⍝SCOUT←RESULT
[30] ⍝ATTACK←RESULT
[31] ⍝ ⎕←OVER
[32] ⍝ ⎕←OTH
[33]  →L×(A<41)


      ∇ RANGE;Y;Z
[1]   REMOTE
[2]   Y←(DATA[;6]=1)∧(DATA[;10]=4)∧(~YIMP)
[3]   Z←Y/[1] DATA
[4]   TGTRNG←(((Z[;8]-Z[;14])*2)+((Z[;9]-Z[;15])*2))*0.5
[5]   AVERNG←(+/TGTRNG)÷⍴TGTRNG
[6]   ⎕←AVERNG


      ∇ NUMRM←REMOTE;Y1;Y2;Y3
[1]   Y1←(DATA[;6]=1)∧(DATA[;7]=101)∧(DATA[;10]=4)
[2]   Y2←(DATA[;6]=1)∧(DATA[;7]=102)∧(DATA[;10]=4)
[3]   Y3←(DATA[;6]=1)∧(DATA[;7]=103)∧(DATA[;10]=4)
[4]   YIMP←Y1∨Y2∨Y3
```

```
[5]    RMIMP←YIMP/[1] DATA
[6]    NUMRM←+/YIMP


       ∇ STIME;A;Y;Z;X
[1]    A←1
[2]    STARTI←⍳0
[3]    STOPTI←⍳0
[4]   L:Y←(DATA[;1]=A)∧((DATA[;6]=1)∨(DATA[;6]=2))
[5]    Z←Y/[1] DATA
[6]    X←Z[1;5]
[7]    STARTI←STARTI,X
[8]    X←Z[(1↑⍴Z);5]
[9]    STOPTI←STOPTI,X
[10]   A←A+1
[11]   →L×(A≤40)


       ∇ NUMSH←TOTSHOT;Y;Z;YY;TI
[1]    A←1
[2]    TOTSH←⍳0
[3]    TISH←⍳0
[4]   L:Y←(DATA[;1]=A)∧(DATA[;6]=1)∧(DATA[;10]=3)
[5]    Z←Y/[1] DATA
[6]    TI←Z[1;2]
[7]    YY←+/Y
[8]    TOTSH←TOTSH,YY
[9]    TISH←TISH,TI
[10]   A←A+1
[11]   NUMSH←⍴TOTSH
[12]   →L×(A≤41)
       ∇
```

APPENDIX F. FITTING PROBABILITY TABLES

A. FIGURE 1-INTERSHOT TIME

Fitting probability tables for the gamma distribution derived for Figure 1.

ANALYSIS OF GAMMA DISTRIBUTION FIT

```
DATA          :  ALLTI
SELECTION     :  ALL
X AXIS LABEL:    MINUTES
SAMPLE SIZE :    740
CENSORING     :  NONE
FREQUENCIES :    1
EST. METHOD :    MAXIMUM LIKELIHOOD
CONF METHOD :    ASYMPTOTIC NORMAL APPROXIMATION
```

		CONF. INTERVALS (95 PERCENT)		COVARIANCE MATRIX OF PARAMETER ESTIMATES	
PARAMETER	ESTIMATE	LOWER	UPPER	ALPHA	BETA
ALPHA	0.69258	0.63248	0.75269	0.00093999	0.0029315
BETA	2.16	1.8952	2.4248	0.0029315	0.018246

	SAMPLE	FITTED
MEAN :	1.496	1.496
STD DEV :	1.8485	1.7976
SKEWNESS:	1.8796	2.4032
KURTOSIS:	6.7926	11.663

PERCENTILES	SAMPLE	FITTED
5:	0.1333	0.024996
10:	0.1333	0.069255
25:	0.1333	0.27305
50:	0.7433	0.86521
75:	2.2699	2.0534
90:	3.664	3.7645
95:	5.5633	5.1115

GOODNESS OF FIT

CHI-SQUARE	:	113.79
DEG FREED:		8
SIGNIF	:	0
KOLM-SMIRN	:	0.2478
SIGNIF	:	6.8091E 40
CRAMER-V M	:	5.6796
SIGNIF	:	< .01
ANDER-DARL	:	37.483
SIGNIF	:	< .01

KS, AD, AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS.

CHI-SQUARE GOODNESS OF FIT TABLE

LOWER	UPPER	OBS	EXP	O-E	((O-E)*2)^{8}E
-INF.	0.9065	418	379.44	38.559	3.9183
0.9065	1.813	54	148.95	94.946	60.524
1.813	2.7195	133	82.997	50.003	30.125
2.7195	3.626	59	49.062	9.9376	2.0128
3.626	4.5325	24	29.812	5.8122	1.1331
4.5325	5.439	14	18.409	4.4089	1.0559
5.439	6.3455	8	11.488	3.4884	1.0592
6.3455	7.252	10	7.2235	2.7765	1.0672

7.252	8.1585	11	4.5674	6.4326	9.0594
8.1585	9.9715	8	4.7489	3.2511	2.2258
9.9715	+INF.	1	3.3034	2.3034	1.6061
TOTAL		740	740		113.79

B. FIGURE 3-TOTAL SHOTS (NORMAL DISTRIBUTION)

Fitting probability tables for the normal distribution for *total shot* data.

ANALYSIS OF NORMAL DISTRIBUTION FIT

```
DATA         :  ATTACK[1;]
SELECTION    :  ALL
X AXIS LABEL:   NUMBER OF ENGAGEMENTS
SAMPLE SIZE :   40
CENSORING    :  NONE
FREQUENCIES :   1
EST. METHOD :   MAXIMUM LIKELIHOOD
CONF METHOD :   EXACT
```

PARAMETER	ESTIMATE	CONF. INTERVALS (95 PERCENT) LOWER	UPPER	COVARIANCE MATRIX OF PARAMETER ESTIMATES MU	SIGMA
MU	14.275	11.701	16.849	1.5787	0
SIGMA	7.9467	6.5923	10.336	0	0.78937

	SAMPLE	FITTED
MEAN :	14.275	14.275
STD DEV :	8.0479	7.9467
SKEWNESS:	0.036654	0
KURTOSIS:	1.9458	3

PERCENTILES	SAMPLE	FITTED
5:	1.5	1.2011
10:	3.5	4.0895
25:	7	8.9175
50:	15	14.275
75:	21	19.633
90:	24	24.46
95:	27	27.349

GOODNESS OF FIT

CHI-SQUARE :	2.1632
DEG FREED:	4
SIGNIF :	0.70577
KOLM-SMIRN :	0.10917
SIGNIF :	0.72709
CRAMER-V M :	0.09102
SIGNIF :	> .15
ANDER-DARL :	0.5194
SIGNIF :	> .15

KS, AD, AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS.

CHI-SQUARE GOODNESS OF FIT TABLE

LOWER	UPPER	OBS	EXP	O-E	((O-E)*2)⁸E
-INF.	4.2857	5	4.1748	0.82524	1.6313E 1
4.2857	8.5714	7	5.2837	1.7163	5.5752E 1
8.5714	12.857	5	7.7094	2.7094	9.5219E 1
12.857	17.143	7	8.4685	1.4685	2.5465E 1
17.143	21.429	8	7.0034	0.99663	1.4183E 1
21.429	25.714	5	4.3602	0.63984	9.3895E 2

25.714	+INF.	3	3.0001	0.00012549	5.2492E 9
TOTAL		40	40		2.1632E0

C. FIGURE 4-TOTAL SHOTS (GAMMA DISTRIBUTION)

Fitting probability information and distributional information for the fit of *total shot* data to the gamma distribution.

ANALYSIS OF GAMMA DISTRIBUTION FIT

DATA : XX
SELECTION : ALL
X AXIS LABEL: NUMBER OF SHOTS
SAMPLE SIZE : 39
CENSORING : NONE
FREQUENCIES : 1
EST. METHOD : MAXIMUM LIKELIHOOD
CONF METHOD : ASYMPTOTIC NORMAL APPROXIMATION

		CONF. INTERVALS (95 PERCENT)		COVARIANCE MATRIX OF PARAMETER ESTIMATES	
PARAMETER	ESTIMATE	LOWER	UPPER	ALPHA	BETA
ALPHA	2.4782	1.4435	3.513	0.27859	0.66414
BETA	5.9078	3.1743	8.6414	0.66414	1.9444

	SAMPLE	FITTED
MEAN :	14.641	14.641
STD DEV :	7.8085	9.3004
SKEWNESS:	0.020886	1.2705
KURTOSIS:	1.9437	5.4211

PERCENTILES	SAMPLE	FITTED
5:	2	3.3229
10:	4	4.6831
25:	7	7.8019
50:	15	12.726
75:	21	19.414
90:	25	27.1
95:	28	32.502

GOODNESS OF FIT

CHI-SQUARE :	9.2522
DEG FREED:	4
SIGNIF :	0.055102
KOLM-SMIRN :	0.16154
SIGNIF :	0.26068
CRAMER-V M :	0.1693
SIGNIF :	> .15
ANDER-DARL :	0.94996
SIGNIF :	> .15

KS, AD, AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS.

CHI-SQUARE GOODNESS OF FIT TABLE

LOWER	UPPER	OBS	EXP	O-E	((O-E)*2)⁸E
-INF.	4.1429	4	3.0618	0.93816	0.28745
4.1429	8.2857	7	7.6744	0.67436	0.059257
8.2857	12.429	5	8.219	3.219	1.2607
12.429	16.571	4	6.7545	2.7545	1.1233
16.571	20.714	8	4.8794	3.1206	1.9958
20.714	24.857	7	3.2655	3.7345	4.2707
24.857	+INF.	4	5.1454	1.1454	0.25498
TOTAL		39	39		9.2522

D. FIGURE 5-MULTIPLE HITS

ANALYSIS OF NEGATIVE BINOMIAL DISTRIBUTION FIT

```
DATA         :  ATTACK[3;]
SELECTION    :  ALL
X AXIS LABEL:   NUMBER OF OCCURANCES PER RUN
SAMPLE SIZE :   40
CENSORING    :  NONE
FREQUENCIES :   1
PARAM SPEC   :  N = 5   AND   P = 0.25889

                              COVARIANCE MATRIX OF
                              PARAMETER ESTIMATES
PARAMETER  ESTIMATE           NOT AVAILABLE
N          5
P          0.25889


           SAMPLE      FITTED               GOODNESS OF FIT
MEAN     :  1.375       1.2945
STD DEV :   1.3144      1.2765               CHI-SQUARE :    0.10777
SKEWNESS:   0.79017     1.189                  DEG FREED:    3
KURTOSIS:   2.6058      4.8137                 SIGNIF   :   0.99089

PERCENTILES   SAMPLE      FITTED
     5:         0           0
    10:         0           0
    25:         0           0
    50:         1           1
    75:         2           2
    90:         4           3
    95:         4           4
```

CHI-SQUARE GOODNESS OF FIT TABLE

LOWER	UPPER	OBS	EXP	O-E	((O-E)*2)⁸E
-INF.	0.5	12	12.651	0.65089	3.3488E 2
0.5	1.5	13	13.008	0.0082408	5.2206E 6
1.5	2.5	8	8.0254	0.025412	8.0463E 5
2.5	+INF.	7	6.3155	0.68454	7.4199E 2
TOTAL		40	40		1.0777E 1

E. FIGURE 6-RANGE OF TARGET WHEN HIT

ANALYSIS OF GAMMA DISTRIBUTION FIT

```
DATA         :  DIS
SELECTION    :  ALL
X AXIS LABEL:   RANGE (M)
```

SAMPLE SIZE : 397
CENSORING : NONE
FREQUENCIES : 1
EST. METHOD : MAXIMUM LIKELIHOOD
CONF METHOD : ASYMPTOTIC NORMAL APPROXIMATION

PARAMETER	ESTIMATE	CONF. INTERVALS (95 PERCENT) LOWER	UPPER	COVARIANCE MATRIX OF PARAMETER ESTIMATES ALPHA	BETA
ALPHA	36.837	31.734	41.939	6.7747	16.119
BETA	87.644	75.421	99.867	16.119	38.876

	SAMPLE	FITTED
MEAN :	3228.5	3228.5
STD DEV :	536.72	531.94
SKEWNESS:	0.5596	0.32953
KURTOSIS:	4.0588	3.1629

PERCENTILES	SAMPLE	FITTED
5:	2407.2	2406.1
10:	2650.9	2568.5
25:	2906.9	2855.9
50:	3130.5	3199.4
75:	3473.8	3569.5
90:	3901.3	3926
95:	4510	4150.3

GOODNESS OF FIT

CHI-SQUARE :	46.803
DEG FREED:	7
SIGNIF :	6.0978E 8
KOLM-SMIRN :	0.10991
SIGNIF :	0.00013659
CRAMER-V M :	0.74379
SIGNIF :	< .025
ANDER-DARL :	4.541
SIGNIF :	< .01

KS, AD, AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS.

CHI-SQUARE GOODNESS OF FIT TABLE

LOWER	UPPER	OBS	EXP	O-E	((O-E)*2)⁸E
-INF.	2329.6	10	13.594	3.5937	0.95004
2329.6	2620.8	25	34.613	9.6126	2.6696
2620.8	2912	67	65.923	1.0771	0.017599
2912	3203.2	111	85.498	25.502	7.6065
3203.2	3494.4	88	80.629	7.3715	0.67394
3494.4	3785.6	50	58.171	8.1713	1.1478
3785.6	4076.8	18	33.423	15.423	7.117
4076.8	4368	7	15.794	8.7937	4.8962
4368	4659.1	18	6.3007	11.699	21.724
4659.1	+INF.	3	3.0553	0.055341	0.0010024
TOTAL		397	397		46.803

APPENDIX G. SAMPLE DATA MATRICES AND VECTORS

A. HISTORY FILE DATA MATRIX

The matrix listed in this appendix is a sample from the larger data matrix used in the TM-I analysis. The data matrix is 8812 X 19 and the sample is only 5 X 19. Each column element provides event information. Below the matrix display is a key used to interpret the data matrix.

```
       SHOT3
row 1--    31      17.687        23     7     18.1892         1
          107        8300      8700     4          80         0
          1          8264      5649     180.7         3052    85.5
          200000

row 2--    31      17.687        23    10     18.2803          1
          107        8300      8700     3          80          0.1985
           20        8378      5244   178.7      3457          0
            1

row 3--    31      17.687        23     8     18.3223          1
          107        8300      8700     4          80          0
           20        8364      5247    178.9       3453        74.3
         200000

row 4--    31      17.687        23    11     18.4136          1
          107        8300      8700     3          80          0.199
           21        8396      5239   178.4      3462          0
            1

row 5--    31      17.687        23    10     18.4788          1
          107        8300      8700     4          80          0
           21        8375      5244    178.8       3456        74.2
         600000
```

```
    Matrix Key
        col 1--replication number
        col 2--engagement start time
        col 3--engagement identification number
        col 4--shot identification number within engagement
        col 5--event type time
        col 6--side identification; 1-BLUE, 2-RED
        col 7--player identification
        col 8--player easting grid
        col 9--player northing grid
```

```
col 10--event type; 1-sensor cycle, 2-select weapon, 3-fire,
        4-round impact, 5-call paired a/c, 6-a/c mission order
col 11--weapon identification number of firer
col 12--event duration minutes
col 13--target identification
col 14--target easting grid
col 15--target northing grid
col 16--gun target line azimuth
col 17--range to target
col 18--number of tgts in search sector, firer speed, aspect
        angle of tgt
col 19--impact results; 100000-miss, 200000-kill, 300000-other,
        400000-false tgt, 500000-dead tgt, 600000-hit, tagret
        speed, number of tgts in FOV
```

B. AH-64 DEATH TIMES

The times for the deaths of the 77 AH-64 kills are listed. These kills are the aggregated number of kills for all 40 replications of the simulation. These data were used to compute the expected lifetime information for the AH-64. Battle time for each replication was computed by subtracting STARTI from STOPTI.

```
      STARTI
8.0166
7.6936 7.6785 7.6875 9.095 8.0393 7.738 9.1455 7.7231 7.6248 7.6902
7.6892 7.6736 7.6462 7.6646 7.675 7.7097 7.6924 7.6731 7.6819 7.7168
7.7195 7.7434 7.6963 7.6543 7.7178 7.7424 7.6709 8.0227 7.7542 9.1206
7.6614 7.771 9.113 7.667 7.7129 7.6531 7.6477 8.0088 7.7024
```

```
      STOPTI
24.2876
23.2463 24.4722 23.7056 24.9863 23.9819 23.7192 24.7549 24.3955
24.3074 24.4741 24.6443 24.8865 24.9885 24.0999 24.498 24.9912 24.7844
23.1594 24.6379 24.2947 24.186 24.8179 24.6921 24.8574 23.51 24.5186
24.9209 24.6055 24.4514 24.9045 24.5859 24.9795 23.7903 23.9724 24.8252
```

```
      KILLTI
23.9619
8.0972 22.9758 8.696 22.7258 8.0522 23.7056 21.6382 22.0039 24.2273
8.1106 21.5859 22.7515 19.4668 8.5237 23.3352 23.9111 8.0513 22.2781
8.0447 20.3591 22.6743 8.0891 22.3477 23.063 24.8865 8.0383 17.0129
22.3455 8.3379 18.9148 19.8621 24.0437 8.0354 20.3005 19.9873 22.8372
8.8005 22.0073 8.269 22.0894 23.1592 8.0359 17.4236 21.2502 22.6826
19.4529 20.1824 24.2051 8.4536 23.7117 24.5557 8.2974 21.8748 19.1589
23.0969 19.9436 21.0972 22.741 21.7332 24.0342 24.4919 22.7791 22.5784
8.0476 8.1267 8.2979 21.0327 20.8997 22.7336 16.4292 23.8584 22.791
8.075 21.0371 22.8516 24.5508
```

C. SHOT EFFECTIVNESS DATA

The two matrices, ATTACK and PAIRED, list the results of the firing data within the history file. The ATTACK matrix lists data for only the AH-64s operating autonomously. The second matrix SCOUT contains the same information but only for those AH-64 aircraft operating in the paired mode with scout aircraft.

```
      ATTACK
10 10  5  0 13 25  6 30 21  8  5
20  7 17 17 22  2  7  4 12 23  1 14 20 11 21
22 17 22 21 19 15 19 15 28  3  6  9 18 26

7  6  2  0 11 20  2 24 16  6  4 14
6 16 15 15  2  7  1 10 18  1 12 15  8 15
18 14 16 17 14 13 18  8 23  2  4  8 10 21

2  1  1  0  2  4  0  4  3  0  1  1
0  1  2  0  0  1  0  0  1  0  1  0  2  1
4  2  1  3  2  1  4  0  4  1  1  2  0  2

3  4  3  0  2  5  4  6  5  2  1  6
1  1  2  7  0  0  3  2  5  0  2  5  3  6
4  3  6  4  5  2  1  7  5  1  2  1  8  5


      PAIRED
 9 0 1 0 0 0 0 0 0 2 0 4 0 0 4 0 0 0 0 1
 3 0 0 3 0 3 0 0 3 3 3 2 0 4 0 1 2 0 4 0

 6 0 1 0 0 0 0 0 0 1 0 3 0 0 3 0 0 0 0 0
 2 0 0 3 0 1 0 0 3 2 2 1 0 3 0 1 1 0 4 0

 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

 3 0 0 0 0 0 0 0 0 1 0 1 0 0 1 0 0 0 0 1
 1 0 0 0 0 2 0 0 0 1 1 1 0 1 0 0 1 0 0 0
```

- row-1, total shots fired during each of the 40 replications of the simulation
- row-2, total hits achieved by the AH-64 in each of the 40 replications
- row-3, number of occurances within a single replication that a target was hit more than once by a Hellfire missile.
- row-4, total number of non-hit missiles; misses, false targets, break laser lock, etc.

APPENDIX H. SAMPLE COLLECTIVE TASK ANALYSIS WORKSHEET

A. COLLECTIVE TASK ANALYSIS WORKSHEET

The task analysis worksheet is the primary instrument used by the training developer to catalog and collect critical information on task performance. The worksheet presented is a sample AH-64 task analysis worksheet.

B. SAMPLE WORKSHEET

COLLECTIVE TASK ANALYSIS WORKSHEET

ORIGINATOR: DOTD, USAAVNC
DATE: Jan 1980

CRITICAL MISSION(S): Perform fire support for manuever elements
Perform anti-armor fire support
Perform fire and maneuver

ELEMENT: AH-64, single aircraft

COLLECTIVE TASK: Engage targets with Hellfire Modular Missile System (HMMS)

CONDITIONS: The AH-64 has occupied its firing position with suitable fields of fire.

Target arrays are composed of threat tanks, BPMs air defense assets in quantaties described by the cumulative distribution function presented in Figure 2.

Battle intensity is such that total shots fired in a 30 minute battle will be greater than or equal to nine shots per aircraft.

STANDARDS: Rate of fire is dependent upon target acquisition, however, copilot-gunner must be able to achieve a mean intershot time of 1.4 minutes in a high intensity battle.

Gunners must be able to achieve 0.75 probabilityof hit for all shots in the autonomous mode and a 0.65 hit probability in the remote engagement mode.

Crew flight tactics and maneuvers must reflect

proper employment techniques that result in a mean survival time of 37 minutes.

SUBTASKS AND STANDARDS: (Lists all pilot and copilot-gunner cockpit and weapon system tasks to conduct a missile firing in all modes. Only reference is made to these tasks and standard because they are numerous.)

EXISTING INDIVIDUAL AND LEADER TASKS: (Lists the platoon and section leader, pilot and copilot-gunner tasks currently taught that are directly related to missile firing and target engagement, again too numerous for listing here.)

NEEDED INDIVIDUAL AND LEADER TASKS: (New tasks that need development for the platoon and section leader as well as the crewmembers. Tasks not listed due to volume.)

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